

Bi-Directional Reflectance Measurements in the Coastal Environment

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LONG-TERM GOALS

My long term goals are to experimentally determine the interrelationships and variability of optical properties in the ocean and atmosphere. I have been concentrating on aspects of scattering, both inelastic and elastic, and measurements of the radiance distribution in the ocean and atmosphere. These measurements can be combined to test and improve radiative transfer models, which are used to predict image and light transmission in the ocean.

OBJECTIVES

The objective of this work is to measure and characterize the in-situ spectral bi-directional reflectance function (BRDF) of benthic surfaces in the littoral zone.

APPROACH

We have built an instrument to measure the in-situ bi-directional reflectance of surfaces at 3 wavelengths (480, 565, and 650 nm were chosen because of the availability of bright LED sources). The instrument is basically a hemisphere with a radius of 10cm, which is placed on the surface to be measured. The surface is sequentially illuminated at angles ranging from 0-65 degrees (0,5,15,25,35,45,55,65 degrees). The reflected light is measured with fibers at the same zenith angles as the illumination and at 29 azimuthal angles from 0 to 360 degrees. The sample area is approximately 1 cm². Light from each viewing direction is collected with fiber optic collectors and then brought into a common "block array" which is imaged on a camera. In this way all viewing angles are collected at a single time greatly decreasing sample acquisition time. The instrument is small and compact enough for diver operation in-situ.

We are using this instrument in conjunction with the ONR sponsored Coastal Benthic Optical Properties (CoBOP) project. This allows us to correlate our BRDF measurements with the measurements of sedimentologists such as Dr. Pam Reid (RSMAS, Univ. of Miami).

WORK COMPLETED

To date we have participated in 2 field exercises in the CoBOP project. We have corrected instrument problems discovered in the first field experiment. We have designed and built sampling devices that improved our ability to sample very soft sediments. Other CoBOP sediment groups also used these

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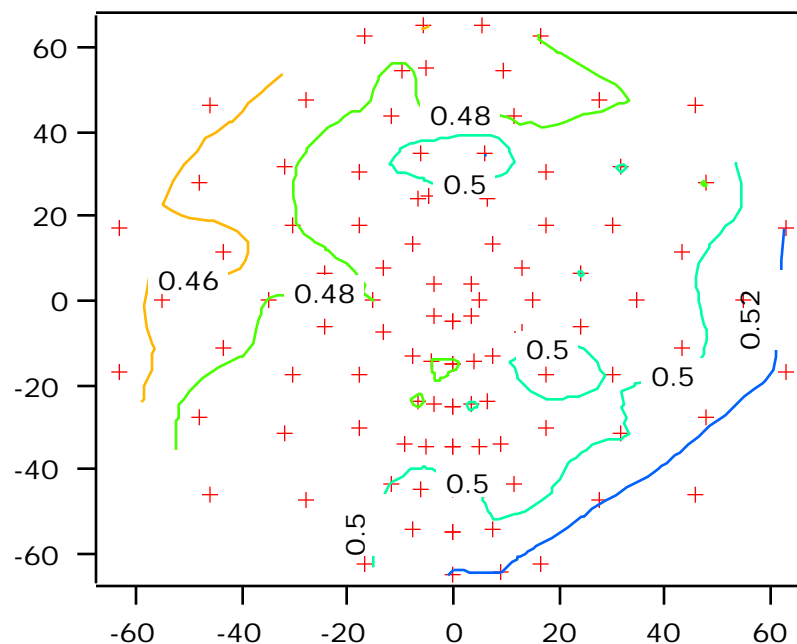
samplers. Extensive laboratory tests of the accuracy/advantages/limitations of the BRDF instrument have been performed. In the most recent experiment we obtained many measurements of differing sediment types in this coastal area. We have reduced this data and are currently working on parameterizing these measurements in a way convenient for inclusion in radiative transfer models.

RESULTS

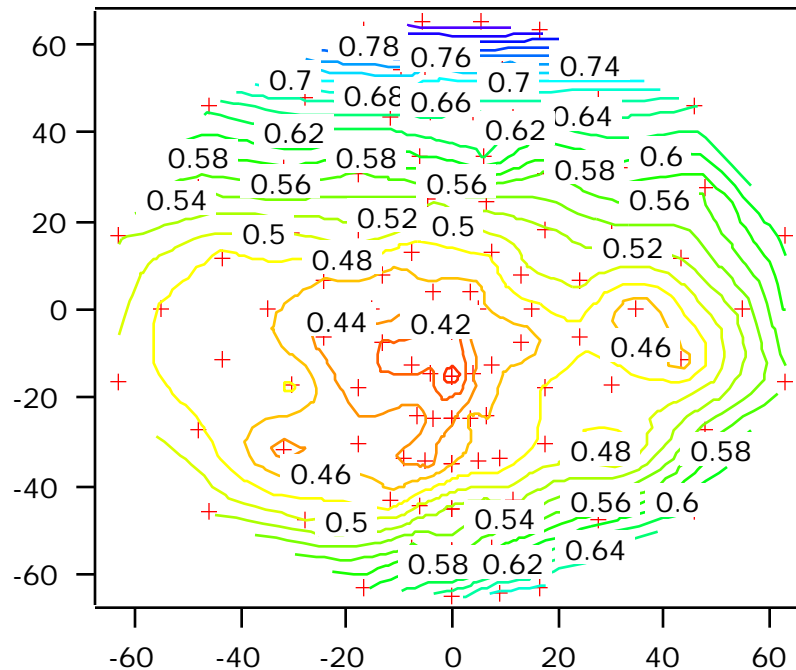
We have just begun looking at the reduced data from the last CoBOP field trip. We have found that the BRDF for natural sediment samples, while lambertian at normal illumination angles (zenith angle 0 degrees) tend to be non-lambertian as the zenith angle moves off axis. Almost all the samples show an enhancement in the “hot spot” varying from a factor of 2 between the light reflected at 0 degrees zenith, and that reflected back to the illumination direction for 65 degree zenith angle illumination. Interestingly most of these samples do not show an increase in specular reflectance for these off-normal illumination angles.

We usually obtain multiple measurements of the same type of sample to allow us to look at the standard deviation between samples to determine how representative our measurement is. For certain samples this standard deviation is as low as 2%. Thus we have a good representation of the BRDF of this type of sediment. For other samples, such as yellow grapestone (a cemented sediment a biological film) the standard deviations are much larger, on the order of 30% indicating much more variation in the BRDF of these surfaces.

As an example of the results found for natural samples the two following plots are shown. Each is for a submerged white sand sample near the Caribbean Marine Research Center (CMRC) on Lee Stocking Island in the Exumas. This is the central site for the CoBOP program.



BRDF for white sand sample. This is a normally illuminated sample (0 zenith degree illumination) at 650nm.



BRDF for white sand sample. This sample is illuminated at 65 degree at 650 nm.

The above two figures are for the same submerged white sand sample. In both cases the illumination wavelength is 650nm. The first figure is for illumination at 0 degree zenith, while the second is for 65 degree illumination. The axes in the figures are the angles off of zenith. The illumination plane is along the 0 on the x-axis, with the specular direction is towards the bottom of the figure. Thus in the second figure, the specular direction would be at (x=0, y=-65), while the back reflection (hot spot) is in the (x=0, y=65) direction. The crosses in the figures show where the viewing angle measurements are performed.

The fact that there are few contours for the normal illumination case illustrates that this sample is near lambertian (commonly assumed BRDF for surfaces). In this case the radiance reflected into any given direction for normal illumination, is nearly constant. The surface looks the same for any viewing angle. In the case of the second figure, the illumination is at 65 degrees. In this case there is a large backscattered enhancement of almost a factor of two. In the forward, specular, direction the reflectance is also enhanced, however to a lesser degree than the backscattering direction. These features seem to be a general feature of most of the samples we have measured.

IMPACT/APPLICATIONS

Knowledge of the BRDF for benthic surfaces will allow more accurate modeling of the light field near the bottom. As this parameter was virtually unknown, all the results will be an advance in the state of knowledge of this parameter.

TRANSITIONS

As results are being obtained, we are transferring this data to the modeling component of the CoBOP program. In addition we have used the instrument to characterize reflectance panels used to evaluate the Laser line scan instrument (FILLS) in the field.

PUBLICATIONS

K. J. Voss, A. Chapin, and Marco Monti, An instrument to measure the Bi-directional reflectance distribution function (BRDF) of surfaces, submitted, Applied Optics.

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